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Mortar making qualities of Illinois sands

Civil Engineering

B. S.

1910

MORTAR MAKING QUALITIES OF ILLINOIS SANDS

BY

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THESIS

FOR THE

DEGREE OF BACHELOR OF SCIENCE

IN

CIVIL ENGINEERING

COLLEGE OF ENGINEERING

UNIVERSITY OF ILLINOIS

PRESENTED JUNE, 1910

UNIVERSITY OF ILLINOIS

COLLEGE OF ENGINEERING.

June 1, 1910

This is to certify that the thesis of WILLIAM KOESTNER entitled Mortar Making Qualities of Illinois Sands is approved by me as meeting this part of the requirements for the degree of Bachelor of Science in Civil Engineering.

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Introduction

Concrete is generally considered as mortar with pieces of hard material embedded in it; the mortar is called the matrix, and the hard material the aggregate. Many experiments have been made to determine the best material for the aggregate, and the proportion of it to be used with a given amount of mortar, but for some reason very little has been done to improve the mortar except by improving the cement used. The standard specifications of the American Railway Engineering and Maintainence of Way Association require that "sand shall be clean, sharp, coarse, and of grains varying in size. - - - - - It may contain clay or loam not to exceed five per cent." But mortars made from sands fulfilling these specifications vary greatly in strength, and sands not fulfilling the specifications may make stronger mortars than

those that do. Briquettes made from some mortars are from three to four times as strong as those made from others which differ only in the kind of sand used. It is therefore evident that the characteristics of the sand used bear a very important relation to the strength of the mortar.

Tests of the mortar making qualities of the sands used in some of the important cities of Illinois were made by Mr. J. W. McManis '07, Mr E. B. Adams '08, and Mr. F. T. Heyle '09. With a view of continuing these tests letters were sent to the city engineers of several cities asking them to send samples of the sand in common use in their respective cities. In all sixteen samples were recived, eight of which were assigned to the writer and eight to Mr. G. A. Barth who is preparing a similar thesis. In addition to these tests were made on the neat cement and Ottowa standard sand for the purpose of comparing the results.

The sands assigned to the writer were as follows:

Sample Number	Sand sent from (Chicago A.A. cement)	Sand obtained at Champaign
1	Ottowa (standard)	
2	Rockford	Rockford
3	Waukegan	Lake Michigan at North Chicago
4	East St. Louis	Mississippi River
5	Moline	Mississippi River
6	La Salle	Little Vermilion R
7	Bloomington	Sugar Creek
8	Joliet	Joliet
9	Beardstown	Beardstown

Object

The object of this thesis is to determine the mortar making qualities of sands used in some of the leading cities of Illinois, and to determine if possible some of the reasons for the variations in the strength of mortars.

Tests were made for tensile strength, fineness, weight, specific gravity, voids, and cleanness.

Description of Tests

Test for tensile strength. The test for the strength of a mortar is naturally more important than any of the physical tests of the sand used. For if mortar made from a particular sand is very strong, it does not matter materially whether the sand is heavy or light, dense or porous, or contains a large or small amount of clay. However, the physical tests of the sand are important for it is by them, in connection with the tests of strength that conclusions may be drawn as to the desirable qualities of a sand. For example, if a number of heavy sands gave strong mortars while a number of light sands gave weak mortars, it would be logical to conclude that it is desirable to use a heavy sand.

Mortar and concrete are used much more in compression than in tension. Mortars that are strongest in tension, however, are also strongest in compression. On account

of the greater ease of making the tests, tensile strengths were determined.

Chicago A A. portland cement in a 1:3 mixture by weight was used in making all mortars. The normal plasticity of a carefully selected sample of this cement, determined in accordance with the specifications of the American Society of Civil Engineers, required 21 per cent of water, and accordingly 9 per cent of water was used in making the 1:3 mixtures.

The mortar was mixed on a slate table which was first moistened to prevent it absorbing water from the mortar. After the mortar was thoroughly mixed the briquettes were molded in three increments. The method by increments was as follows. About one third of each of six molds was filled with mortar which was pressed in firmly with the fingers. The remaining two thirds were filled and pressed in the same manner after which the tops were firmly troweled, care being

taken to trowel each briquette the same amount.

In general six briquettes were molded at the same time in one gang mold, only sufficient mortar for this number being mixed in each batch. After molding, the briquettes were covered with a damp cloth and pan, and were allowed to remain in this condition for 24 hours after which the briquettes were taken from the molds and stored in running water maintained at about 70° Fahrenheit. At the end of seven days from the time of molding, six briquettes—two from each batch—were tested. In the same way six were broken at the ages of 28 and 90 days respectively.

The briquettes were of standard shape with a breaking area of ~~about~~ one square inch. A Riehle automatic machine was used in breaking them. The load was applied at the rate of 600# per minute as as recommended by the American Society of Civil Engineers

Cleanness

Clay and loam are composed of particles much finer and lighter than the grains of sand and hence will remain suspended in water longer than sand. In order to determine the amount of these materials in any sand, the following method was used. 1000 grams were put in a glass jar of about a gallon capacity filled with water. The sand was stirred thoroughly to wash the clay and loam from the grains, and allowed to settle for about a minute and a half, after which the water was drained off by a siphon of ¼" tubing. In order that no sand should be carried off with water the end of the siphon in the jar was kept just a very little below the surface of the water and was lowered as the water surface dropped, until only about an inch of water covered the sand. More water was then added, and the operation was repeated. This was

continued until the water became nearly clear in a very short time after stirring. As much water as possible was then drained off, and the sand dried thoroughly over a coil of steam pipes. After drying it was reweighed and the amount of clay was found by subtracting the weight after washing and drying from 1000 grams.

Only four of the sands were washed since the amount of clay in the others was not appreciable. The amounts of clay in these are given in column 3 of table 5, page 33.

Test for Fineness

After the sands had been washed and dried and the percentages of clay determined, sieve analyses were made, using the washed samples. The sand was put in a number 5 sieve below which were the numbers 8, 10, 16, 20, 30, 40, 60, 74, 100, 150, and 200 sieves and a pan, in the order given. These were put

in a Per Se Testing Sieve Agitator which was driven by power at the rate of about 100 R. P. M. After forty minutes of continuous shaking the sieves were removed, and the sieve—generally the number 60—containing the most material, was shaken by hand for one minute. If less than one gram passed the sieve in that time it was considered that the sifting was complete. The amounts of sand retained on the different sieves and in the pan were carefully weighed, and the amounts smaller than the different meshes were computed by adding the amounts retained on all the smaller sieves, the amount of suspended matter being included with that passing the No. 200 sieve. The results are given in table 5, page 33, and from these results curves are plotted. (See pages 36–43)

Specific Gravity

The sketch on the following page shows the simple apparatus for

Schumans Specific Gravity Flask.

determining specific gravities. It is known as a Schuman's specific gravity flask and consists of a long tube graduated to cubic centimeters which fits tightly into the neck of a small bottle holding about a pint. The bottle and also the bottom of the tube was filled with water and the reading on the graduated tube was taken. Then 50 grams of sand were poured slowly into the glass tube through a funnel at the top. After this another reading of the glass tube was taken. By subtracting the first reading from the second the number of cubic centimeters of water displaced by the sand was obtained. Then the specific gravity was computed from the equation, $\frac{50}{W}$ = specific gravity, in which W is the number of cubic centimeters of water displaced by the 50 grams of sand. The operation was repeated for each sand as a check. The specific

gravities of the different samples are given on table 6, page 34.

Weight and Percentage of Voids

In order to find the percentage of voids it was first necessary to determine the weight of a known volume of sand. A graduated cylinder of 500 c.c. capacity was filled with sand and the weight of the sand determined. The method of filling the cylinder was as follows. Enough sand to fill about one fifteenth of the cylinder was poured in; and this was compacted by bumping the cylinder twelve times against a pad on the table. Then more sand was added and the operation repeated. This was continued until the cylinder was full, and then the sand was weighed. In one trial the sand was likely to become packed tighter than in another. There was also some chance for error in noting when the sand reached the 500 c.c mark, due to the uneven surface of

the sand. For these reasons the test was repeated several times until there was a maximum variation of not more than 1 o/o of the total weight for three weighings of the sand.

The percentage of voids was determined by the following method:

Let S = Specific Gravity

P = Per cent of voids

M = Mass in grams of 500 c.c. of sand

Then $500\,S$ = weight in grams of 500 c.c. of solid material

And $P = \frac{500\,S - M}{M} \times 100$

The voids in the different sands are given in table 6, page 34.

Description of Sands

Sample No. 1.

Sample No. 1. Ottowa standard sand is light gray, nearly white in color, and is pure quartz. The grains are of practically the same size, since they were screened through a No. 20 sieve and caught

on a No. 30. It has a sp. gravity of 2.635, weighs 107 lbs. per cubic foot, contains 34.5 percent of voids, and makes a stronger mortar than any of the other sands tested.

<u>Sample No. 2.</u> This sand was obtained from the Rockford Sand and Gravel Company. It was taken from a sewer trench, and is of the same vein that underlies the easterly portion of the city. There is practically an inexhaustible supply.

Sample No. 2

The material is well graded, and there is practically no clay or loam in it. The smaller particles, which are principally quartz, are sharp and angular but the larger pieces have rounded edges. It has a specific gravity of 2.66, ~~and~~ weighs 110 lbs. per cubic foot, and contains 33.6 percent of voids. At the age of 7 days its mortar was strongest, and it was second in strength at 28 and 90 days. It is a very good mortar sand.

Sample No. 3. Waukegan sand has been used in brick and concrete work for many years, and mortar made from it is said to be durable. The material came from the shore of Lake Michigan at North Chicago.

Sample No-3

There is a large deposite, the character of which varies considerably on account of storms. The sand is grayish brown in color, and includes a number of different kinds of material including sandstone, limestone, quartz, and granite. The amount of suspended matter is inappreciable, and the material is fairly well graded except that it does not contain many large particles. It contains 33.7 per cent of voids, has a specific gravity of 2.695 and weighs 112 lbs. per cubic foot. It ranks fifth in strength at 7 days, and third at 28 and 90 days.

Sample No. 4. This sand was sent by the city engineer of East St Louis

It was takin from a large deposit in the bed of the Mississippi River opposite the city. For many years the sand has been used in East St. Louis and vicinity in all kinds of concrete work and brick buildings. It is of a light gray color, and may be classed as "sharp" although some of the larger particles are rounded considerably. Nearly all, save the larger pebbles, are quartz. It is a very clean sand with a fairly high specific gravity (2.639) and the lowest percentage of voids (30.1%). It is the heaviest sand tested, weighing 115 lbs. per cubic foot, and ranks third in strength at 7 days, and fourth at 28 and 90 days.

Sample No. 4

<u>Sample Number 5</u>. All the sand that is used in Moline is pumped from the bed of the Mississippi a few miles above the city. It is believed that the sample sent by the city engineer

Sample No. 5

is fairly representative of the sand used in that town although the banks shift with the current, and consequently the sand varies in fineness and quality. As regards fineness this particular sample is about the average of the eight sands from different cities that were tested by the writer. Its weight is 110 lbs. per cubic foot, its specific gravity is 2.624, and the voids are 32.9 per cent of the total volume. This may be classed as an average sand.

<u>Sample No. 6</u>. This sand was taken from the Little Vermilion River north of La Salle. It is poorly graded, and next to the Beardstown sand is the finest tested. Its grains are rounded, and it contains 3.2 per cent of suspended matter nearly all of which is black loam. It has a fairly high specific gravity of 2.635, but weighs only 104 lbs. per cubic foot and contains 36.4 per cent of voids. It ranks sixth in strength at 28 days,

Sample No. 6.

and seventh at 7 and 90 days. The color is a very dark gray.

Sample No. 7. The sand sent from Bloomington, was obtained from pits along the valley of Sugar Creek. There are several of these pits a mile or more apart, but the quality of the sand found in them does not vary greatly. It is the best graded sand of any, and most of the particles have fairly sharp edges. It has a yellowish color approaching that of yellow clay. The test for cleanness showed that it contains nearly 8 per cent of suspended matter. In spite of this it ranked above three of the sands in strength at 7 and 90 days. (See Discussion page 22,23). It has only 32.2 per cent of voids, but its specific gravity is only 2.622. It weighs 112 lbs. per cubic foot.

Sample No. 7

Sample No. 8. This sand comes from pits located on the outskirts of the city of Joliet, and the quality of

the sand from the different pits is by no means uniform. The quantity in any one place is limited and new sources are opened quite frequently. The particular sand tested is exceedingly dirty,

Sample No. 8.

containing 18.3 per cent of suspended matter, and the particles are not well graded in size. Many of the grains are so soft that they can be crushed between the fingers. The sand is "such as is commonly used in our concrete foundation work for streets and buildings." It would apparently be economical to wash the clay from this sand, for the strength at 28 days is increased more than 60% by so doing. (See table 4, page 32, also Discussion pages 23 and 24.)

<u>Sample No. 9</u>. Beardstown sand came from a bank near the city. The deposites are large, but vary considerably in character. Since 1857, when the town was built, the

sand has been used in cement walks, in mortar and plaster, and for pavement filler and cushion, and is said to be satisfactory. It is the finest sand tested and it contains 4.4 per cent of clay. It has 37.9 per cent of voids, is lighter than all but the Joliet sand, and has the lowest specific gravity - 2.605.

Sample No. 9.

Discussion

One of the principal conclusions to be drawn from this series of tests is that the quality of the sand is the main factor affecting the strength of the mortar. It will be noted in Table 7 that the standard sand yielded the strongest mortar, which is somewhat surprising in view of the fact that it is composed of grains of practically the same size. It is probable, however, that the exceptional strength of the material (pure quartz), together

with the rough surface of the grains which causes the cement to adhere strongly, more than offsets the detrimental effect of uniform size and globular shape of the grains. Although the mortar is quite strong it would probably be still stronger if the sand were well graded.

Sands No. 2-5 inclusive were considerably stronger than the others. These sands all have hard grains and contain considerable quartz. The other sands — No. 6-9 inclusive — contain less quartz, and the other grains in general are so soft that they can be crushed quite easily. On breaking the briquettes it was noticed in many cases that a number of the grains of the weak sands were broken squarely in two, which showed that the grains had less strength than the adhesion of the cement to them.

The sands from Joliet and the Little Vermilion River are the only ones having higher specific gravity than any of the four strongest sands — those from Rockford, Waukegan, East St. Louis,

and Moline. The Bloomington sand is the only one with less voids, heavier weight, or better grading. From this we may conclude that it is desirable to have a heavy, well graded sand with a minimum amount of voids.

A large amount of clay or loam in sand makes the mortar much weaker, but a small amount is beneficial in some cases. The little Vermilion River sand (see table 4) is about 50 o/o stronger with its 3.2 o/o of clay than without it. Since the two sets of briquettes in this case were not made at the same time the conditions affecting their strength may have changed considerably, and hence the results do not indicate positively that the washing had this effect. These tests need to be verified before a definite conclusion about them is made. By removing 18.3 o/o of clay from the Joliet sand the strength of the mortar was increased more than 60 o/o. Removing 4.3 o/o from the sand from Beardstown increased its strength about 28 o/o, while the removal of

8 o/o from the Bloomington sand increased the strength only about 12 o/o. About 4 or 5 o/o of clay is the maximum amount a sand should contain.

Results in Baker's "Masonry Construction" (page 141) show that the less the percentage of voids in concrete the greater the strength, other things being the same. It is natural to suppose that the same is true of sand mortars. And some authorities have claimed that the material whose sieve analysis curve approaches a parabola will make the strongest mortar. The results of these tests indicate that these theories may be true but give no definite proof since there are many other differences in the sands. The Bloomington sand, sample no. 7, is nearer this ideal grading than any other tested and has next to the smallest percentage of voids, but it ranked only seventh in strength at 28 days. When 8 o/o of clay was removed from it, it ranked sixth in strength. The engineer forwarding the sand said

that it "is used in buildings and pavement foundations, but not in cement walks or work requiring clean sand." A large amount of clay in sand causes a weaker mortar, but the amount of clay is by no means the only factor affecting the strength. Washing the clay from this sand did not materially increase the strength. And in spite of the fact that it is well graded it ranks comparatively low in strength. These facts are more evidences that the quality of material composing the grains is the greatest factor affecting the strength of the mortar.

The Beardstown and Joliet sands are by far the poorest tested. While it cannot be definitely stated, without experiments, how rich a mixture it would actually require to make mortar from these sands as strong as 1:3 mortar of Rockford, Waukegan, or East St. Louis sand, it is conservative to estimate that at least a 1:1 mixture would be required. If such is the case it would doubtless be more economical to ship in sand such as that

from Rockford, Waukegan, or East St. Louis, even if the price at delivery is considerably more, for by using a 1:3 instead of a 1:1 mortar more than 2 barrels of cement per cubic yard of mortar is saved, and only about 1/3 cubic yard more of sand is needed. (See Baker's "Masonry Construction" p. 120).

Suppose for example that the total costs per cu. yd. of Joliet and Rockford sands for work in Joliet wer \$0.25 and \$2.00 respectively, and that portland cement costs \$1.50 per barrel, Then, using the proportions given in "Masonry Construction," page 120, the totals costs of materials for a cubic yard of each kind of mortar would be as follows.

1:1 mortar of Joliet sand

4.43 bbls. cement @ \$1.50	= 6.65
0.61 cu. yd. sand @ \$0.25	= 0.15
Total	= \$6.80

1:3 mortar of Rockford sand

2.36 bbls. cement @ \$1.50	= \$3.55
0.95 cu. yd. sand @ \$2.00	= 1.90
Total	= \$5.45

In such a case it would be

decidedly economical to use the Rockford sand.

Rockford, East St. Louis, and Waukegan sands are very good for mortar making purposes. The sands from Moline, Bloomington, and the Little Vermilion River are fairly good, and it is perhaps economical to use them rather than pay freights on better sands, except in cases of the most important constructions where maximum strength is required. Beardstown and Joliet sands are very poor, however, and should not be used for mortar making unless a better sand can not be obtained.

Specifications

In view of the results of these tests the writer recommends that specifications for sand contain the following items.

1. When molded in three increments with 9 o/o of water, 1:3 sand mortar briquettes (by weight) shall develop a tensile strength at 7 and 28 days

equal to one fourth of the strength of neat cement briquettes of the same age.

2. A considerable portion of the grains shall be of quartz or material equally hard and durable. It is desirable that the grains have sharp edges, and that the faces of the grains be rough.

3. The sand shall contain not more than 34 per cent of voids, and shall weigh not less than 105 lbs. per cubic foot. In weighing, the sand shall be thoroughly dry, and shall be compacted by being thoroughly shaken, but not rammed. The percentage of voids is to be computed from the specific gravity and weight of the sand. The specific may be obtained with a Schumans specific gravity flask, or by some similar method.

4. Sand shall contain no sticks, leaves, pieces of paper, straw, or shavings. It is desirable that not more than 90 o/o shall pass the No. 16 sieve.

Description of Tables

Tables 1, 2, and 3 give the strengths of briquettes at 7, 28, and 90 days respectively. Table 4 gives results that may show something of the effect of clay and loam upon the strength of sand. As noted under the table all briquettes were made the same day except those of the Little Vermilion River sand. The briquettes made from this sand after washing were molded 15 days later than those made from the unwashed sand, which may account for the mortar being strongest when the sand was not washed.

Table 5 gives the results of the sieve analysis tests. The amount passing any sieve is found by adding the amounts retained on all smaller sieves and in the pan including also the suspended matter. Also in column three of Table 5 are given the percentages of clay and loam that were removed from four of the sands by washing them.

The specific gravities, weights, and percentages of voids in the sands are given in table 6. The methods of computing the specific gravity and the per cent of voids in a sand are given on pages 10 and 12.

Table 7 gives a partial summary of the results of the different tests. This table is mainly for the purpose of comparing the sands for the sake of seeing what qualities are desirable in a sand.

The results of the sieve analysis tests are shown graphically on pages 36 to 43. Besides plotting a curve to show the grading of each sand, a parabola is plotted. A curve that has a parabola for its sieve analysis curve is supposed to have an ideal grading.

TABLE I.

TENSILE STRENGTH OF 7 DAY BRIQUETTES

Sample No.	Sand Obtained From	Tensile Strength of 1:3 Mortar–lbs.						Average
	(Neat Cement)	605	650	705	700	665	670	666
1	Ottowa (Standard)	160	175	185	200	160	170	175
2.	Rockford	205	185	185	170	205	180	188
3	Waukegan	150	135	140	155	170	135	148
4	East St. Louis	170	185	170	160	170	175	172
5	Moline	150	135	130	160	145	165	148
6	Little Vermilion R.	130	120	130	110	100	110	117
7	Bloomington	130	120	115	115	120	120	120
8	Joliet		80	75	65	75	90	77
9	Beardstown	95	80	90	90	90	70	86

TABLE 2.

TENSILE STRENGTH OF 28 DAY BRIQUETTES

Sample No.	Sand Obtained from	Tensile Strength of 1:3 Mortar–lbs.						Average
	(Neat Cement.)	770	760	820	750	795	735	772
1	Ottowa(Standard)	270	255	265	275	270	250	264
2	Rockford.	270	220	250	260	255	245	250
3	Waukegan	180	215	225	220	260	230	222
4	East St. Louis	195	210	205	190	210	230	207
5	Moline	200	190	220	210	215	190	204
6	Little Vermilion R.	200	180	175	190	200	170	186
7	Bloomington	160	180	170	140	170	165	164
8	Joliet	80	90	90	115	100	115	98
9	Beardstown	115	105	100	105	115	100	108

TABLE 3

TENSILE STRENGTH OF 90 DAY BRIQUETTES

Sample No.	Sand Obtained From	Tensile Strength of 1:3 Mortar-lbs.						Average
	(Neat Cement)	795	820	835	825	820	820	819
1.	Ottowa (Standard)	315	310	335	330	325	330	324
2.	Rockford	245	265	345	325	305	285	295
3.	Waukegan.	290	260	270	300	300	300	287
4.	East. St. Louis.	285	275	230	245	245	260	257
5.	Moline	210	235	230	210	240	230	226
6	Little Vermilion R.	175	200	185	190	210	190	192
7	Bloomington	215	190	200	195	210	225	206
8	Joliet	110	120	160	120	125	130	128
9	Beardstown	145	130	150	135	135	145	140

TABLE 4

EFFECT OF CLAY on STRENGTH OF 1:3 MORTAR

Sample No.	Sand Obtained From	Tensile Strength at 28 Days – lbs.						Average	Remarks
6	L. Vermilion R.	120	115	110	120	125	130	120	Sand washed
6_2	L. Vermilion R.	200	180	175	190	200	170	186	Sand not washed. 3.2% clay
7_1	Bloomington	205	180	160	175	190	210	187	Washed
7_2	Bloomington	165	165	185	160	140	185	167	Not washed. 8% clay
8_1	Joliet	170	150	165	165	160	155	161	Washed
8_2	Joliet	125	110	95	110	120	110	112	Not washed. 18.3% clay
9_1	Beardstown	115	125	125	125	125	130	124	Washed
9_2	Beardstown	85	110	100	90	110	85	97	Not washed. 4.4% clay

Note: Briquettes No. 6_2 were molded 15 days later than no. 6
All others were molded the same day.

TABLE 5

FINENESS TESTS

Sample Number	Sand Obtained From	% Suspended Matter	Per cents Passing Sieves No.												
			200	150	100	74	60	40	30	20	16	10	8	5	0.2"
1	Ottowa (Standard)	0	0	0	0	0	0	0	0	100	100	100	100	100	100
2	Rockford	0.00	0.08	0.15	0.35	1.95	4.06	20.86	53.34	80.06	83.51	94.50	98.14	99.66	100.00
3	Waukegan	0.00	0.04	0.09	0.65	8.57	11.92	38.22	61.58	81.85	85.65	97.90	98.94	99.50	100.00
4	East St. Louis	0.00	0.41	0.66	1.80	5.89	9.92	39.52	55.07	79.33	82.50	95.81	97.76	99.40	100.00
5	Moline	0.00	0.04	0.07	0.17	1.61	4.32	35.24	67.17	85.84	88.59	96.94	98.31	99.39	100.00
6	Little Vermilion R.	3.21	4.22	4.48	6.78	16.47	26.02	87.72	97.88	99.33	99.47	99.82	99.90	99.95	100.00
7	Bloomington	7.97	8.98	9.70	11.31	19.75	21.63	42.92	56.37	67.05	69.80	85.84	91.10	96.62	100.00
8	Joliet	18.32	19.28	19.49	20.14	21.08	22.17	32.43	63.66	94.76	96.84	99.43	99.67	99.89	100.00
9	Beardstown	4.42	6.58	7.60	13.20	35.37	47.50	97.08	99.67	99.93	99.96	99.98	100.00	100.00	100.00

TABLE 6

SPECIFIC GRAVITIES, WEIGHTS, and PER CENTS of VOIDS.

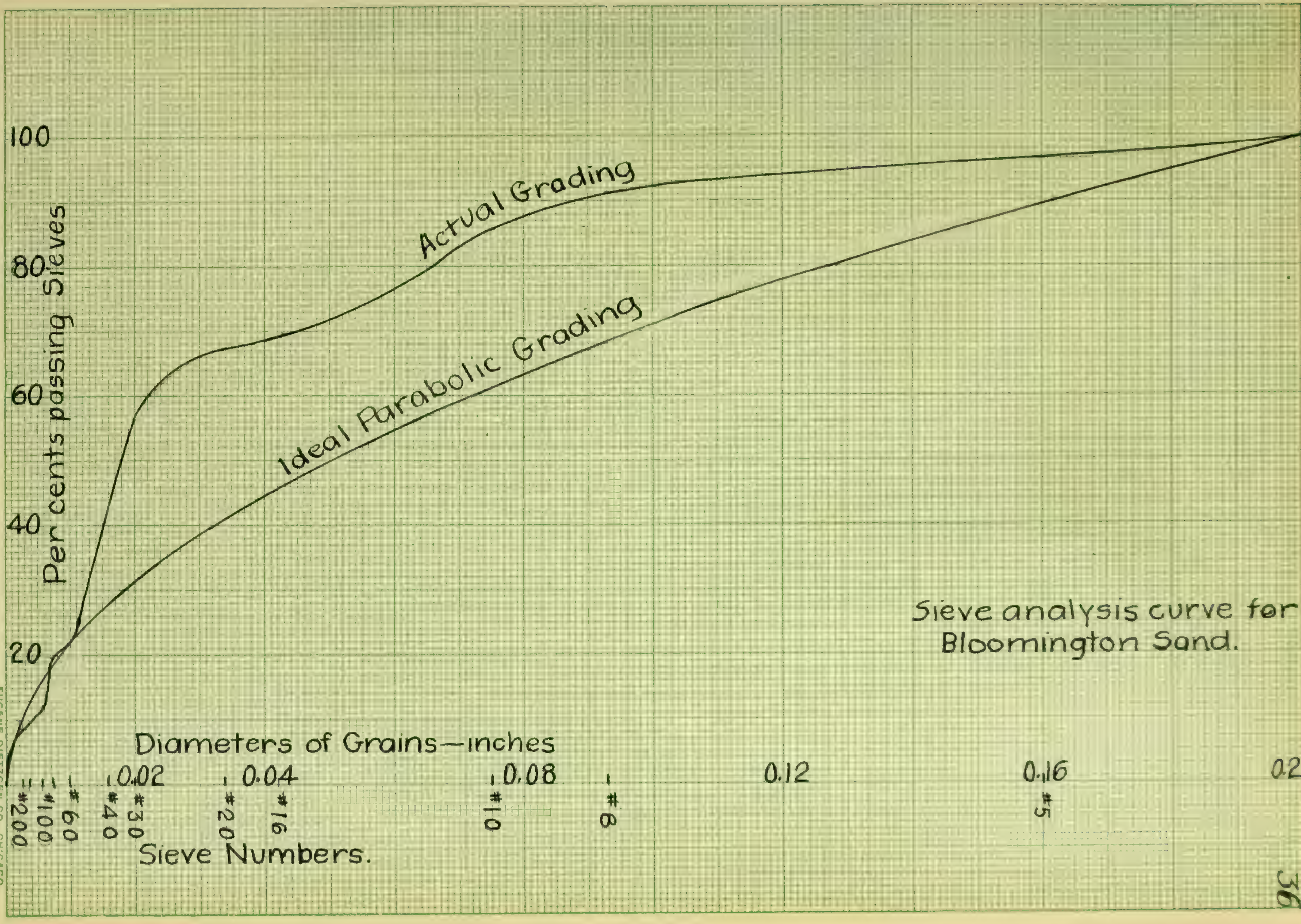
Sample No.	Sand Obtained From	C.C. of Water Displaced by 50gr. sand Average 2 trials	Specific Gravity	Wt. of 500 c.c. of Sand—grams Average of 3 trials	Percent of Voids
1	Ottowa (Standard	19.00	2.635	861.7	34.5
2	Rockford	18.80	2.660	882.4	33.6
3	Waukegan	18.55	2.695	894.2	33.7
4	East St. Louis	18.97	2.639	918.3	30.1
5	Moline	19.05	2.624	881.6	32.9
6	Little Vermilion R.	19.00	2.635	838.4	36.4
7	Bloomington	19.08	2.622	890.7	32.2
8	Joliet	18.72	2.670	794.1	40.0
9	Beardstown.	19.20	2.605	808.9	37.9

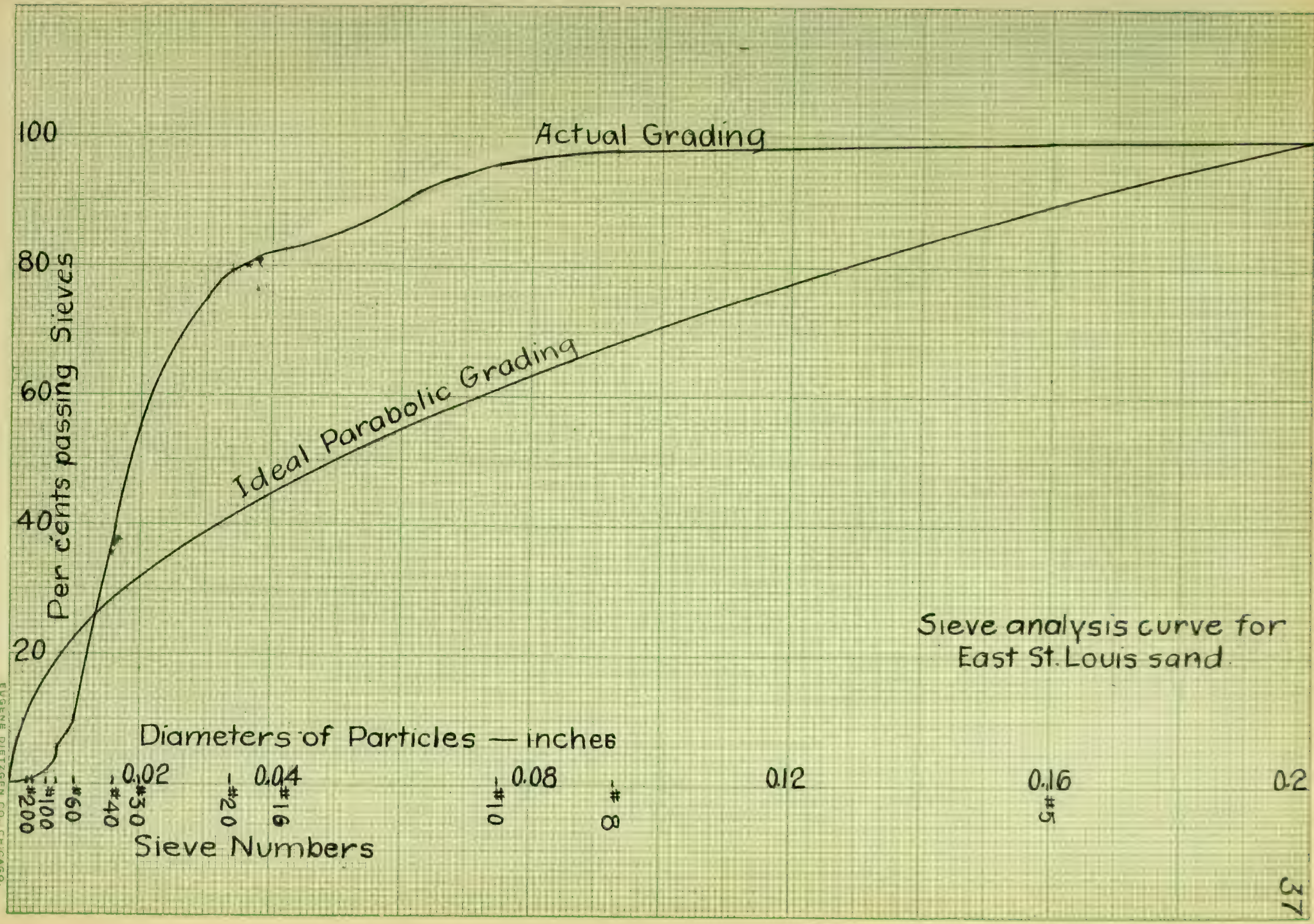
TABLE 7

COMPARISON OF RESULTS

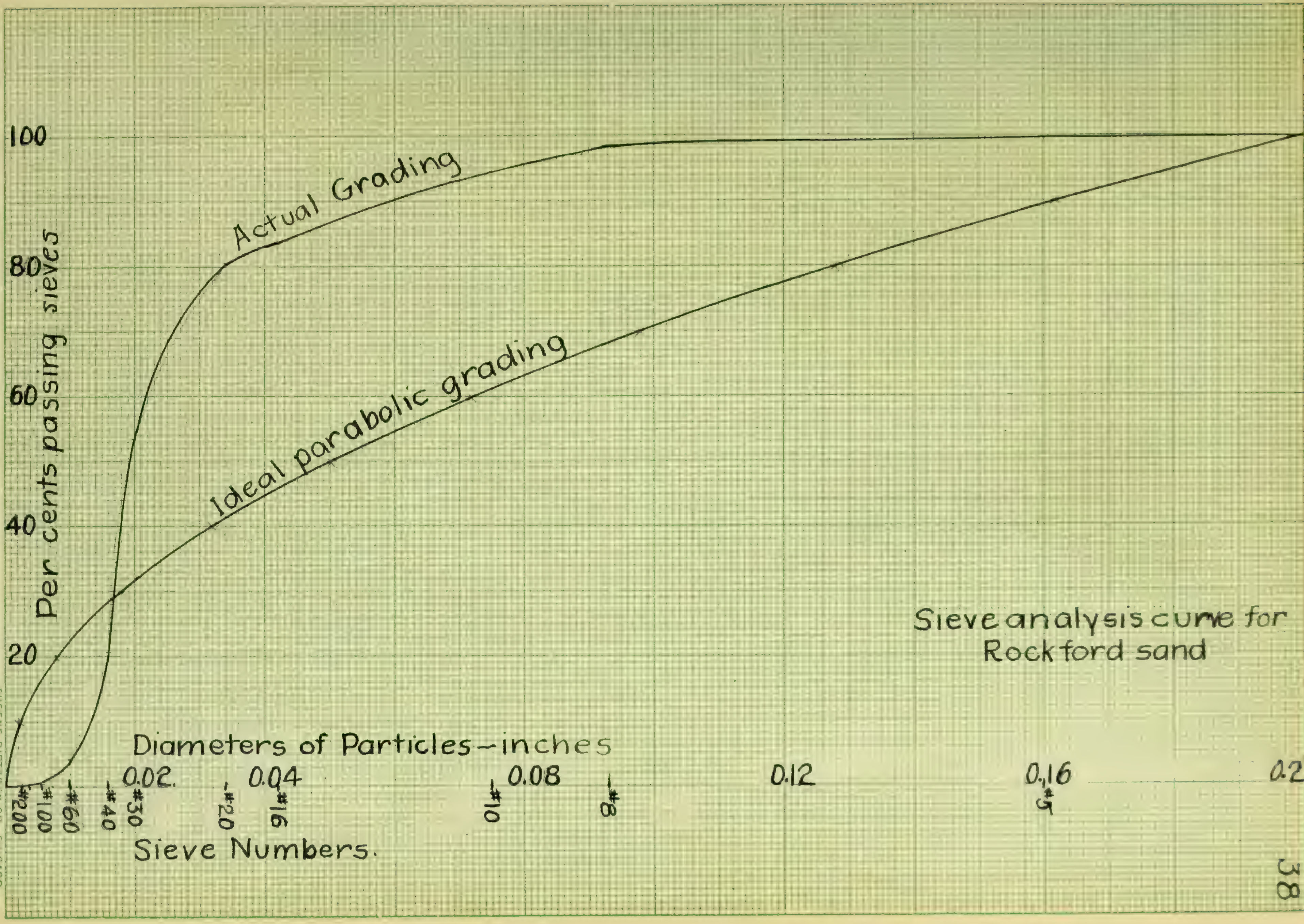
Sample No.	Sand Obtained From	Rank in Strength at			Rank in Weight	Rank in Sp. Grav.	Rank as to Least Voids	Rank as to Grading
		7 days	28 days	90 days				
1	Ottowa (Standard)	2	1	1	6	5	6	
2	Rockford	1	2	2	4	3	4	3
3	Waukegan	5	3	3	2	1	5	4
4	East St. Louis	3	4	4	1	4	1	2
5	Moline	4	5	5	5	7	3	5
6	Little Vermilion R.	7	6	7	7	5	7	7
7	Bloomington	6	7	6	3	8	2	1
8	Joliet	8	9	9	9	2	9	6
9	Beardstown	9	8	8	8	9	8	8

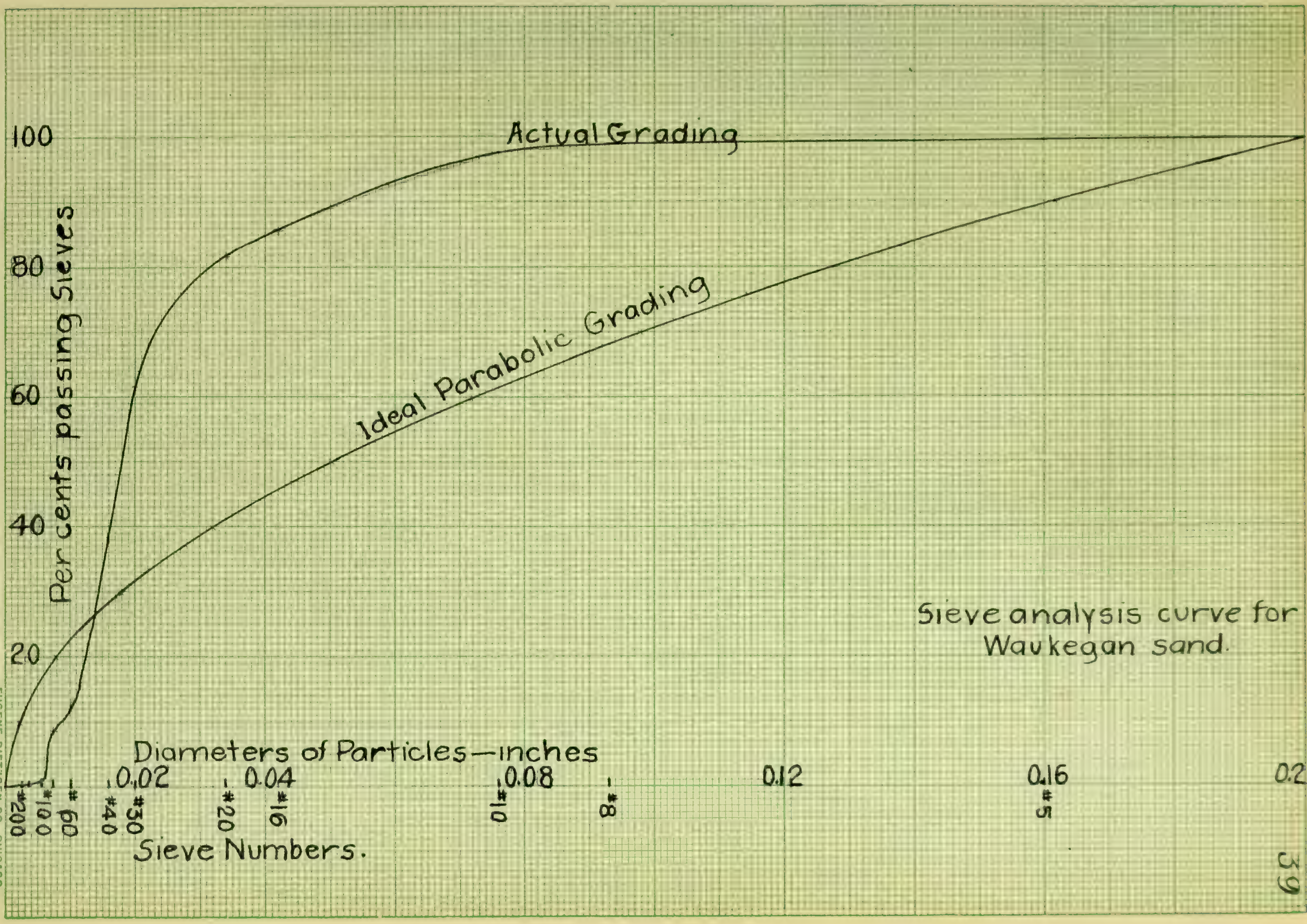
Note: In column 9, rank 1 means that there is the least area between the sieve analysis curve of that sand and a parabola through the point (0.2", 100%). See curves.

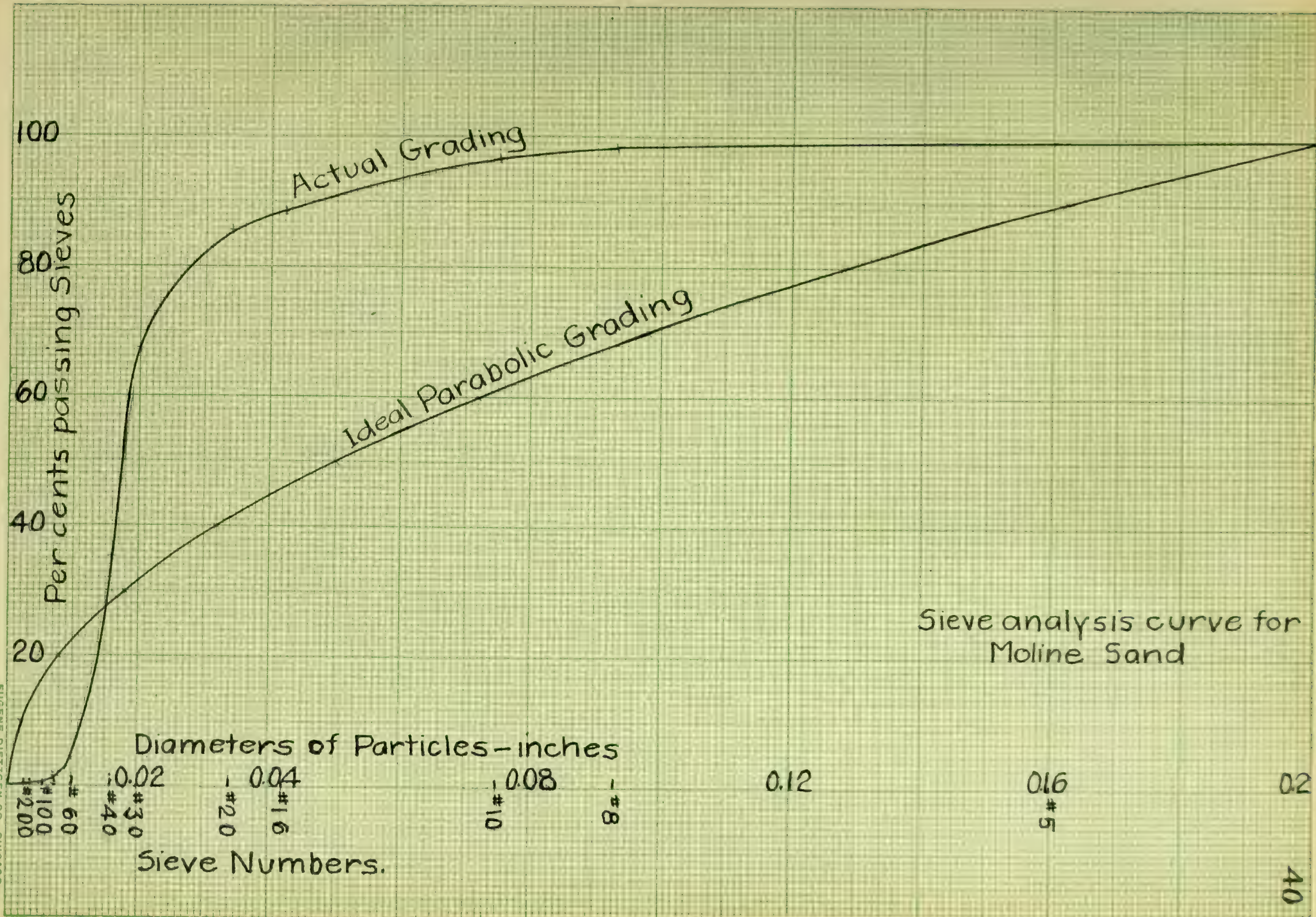

Sieve analysis curve for
Bloomington Sand.
Actual Grading
Ideal Parabolic Grading
Per cents passing Sieves
100
80
60
40
20
Diameters of Grains—inches
0.02
0.04
0.08
0.12
0.16
0.2
#200
#100
#60
#40
#30
#20
#16
#10
#8
#5
Sieve Numbers.
EUGENE DIETZGEN CO., CHICAGO.

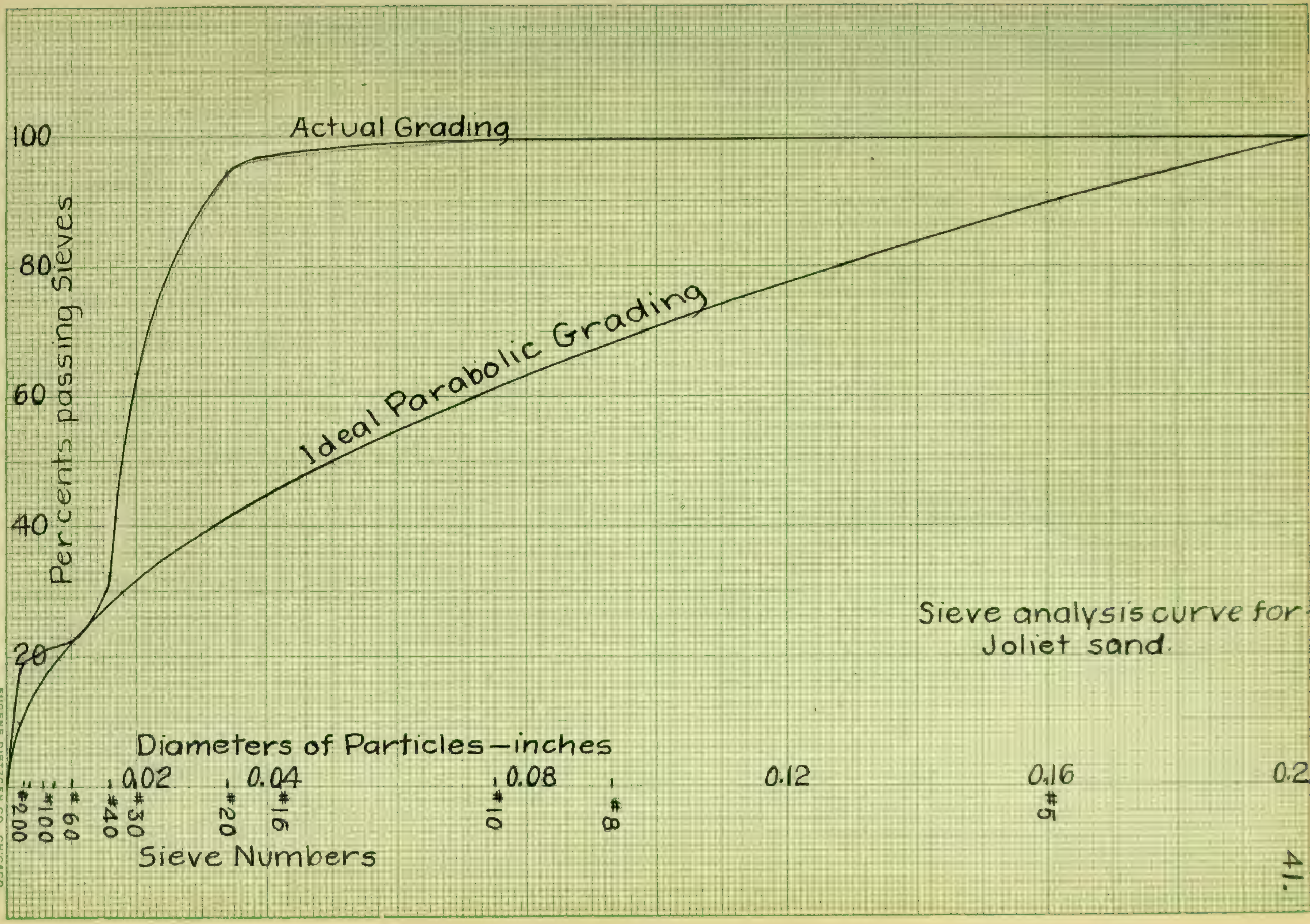


Per cents passing Sieves
100
80
60
40
20
Actual Grading
Ideal Parabolic Grading
Sieve analysis curve for
East St. Louis sand
Diameters of Particles — inches
0.02
0.04
0.08
0.12
0.16
0.2
#200
#100
#60
#40
#30
#20
#16
#10
#8
#5
Sieve Numbers
37
EUGENE DIETZGEN CO., CHICAGO.

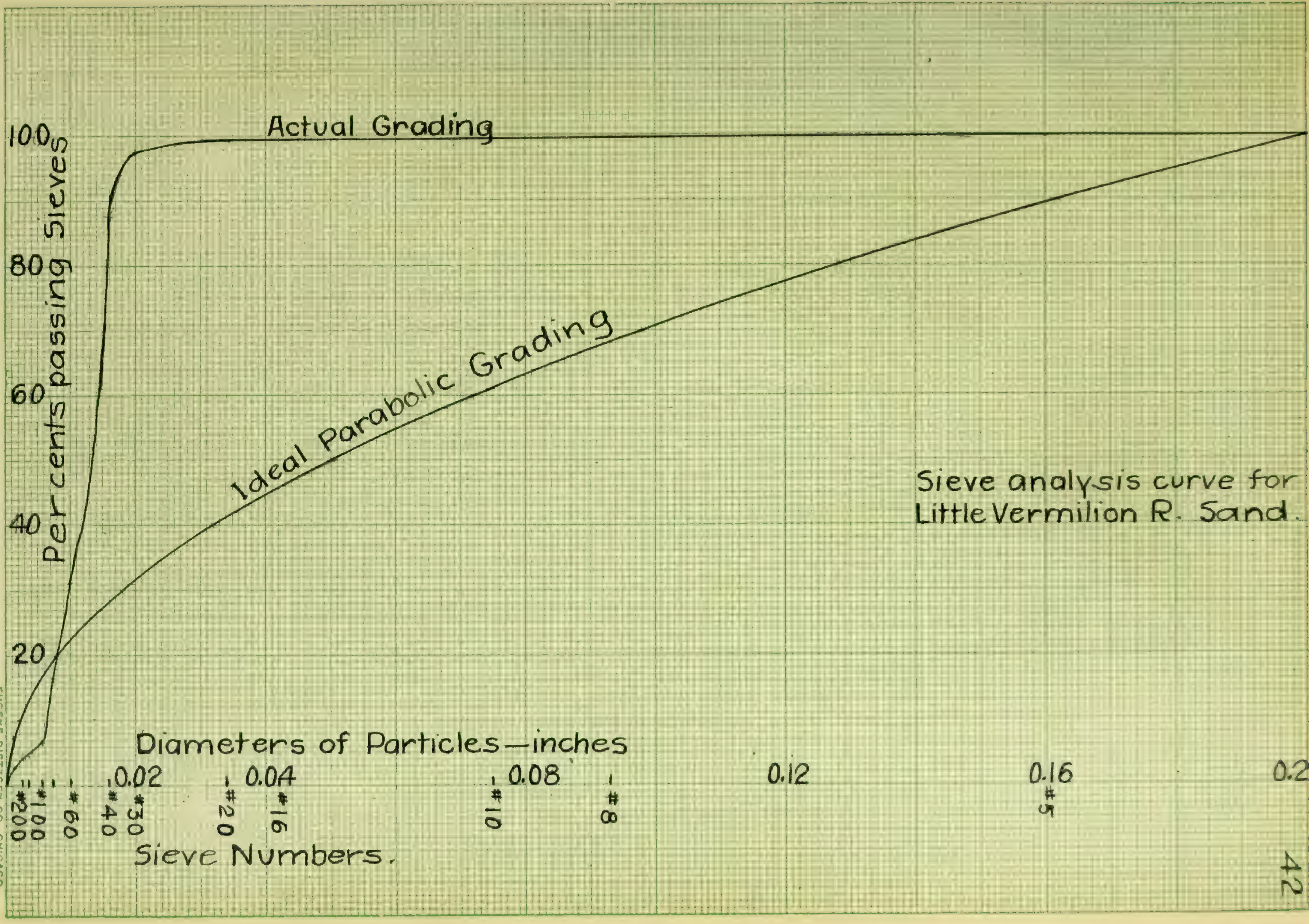

Sieve analysis curve for
Rockford sand
Actual Grading
Ideal parabolic grading
Per cents passing sieves
100
80
60
40
20
Diameters of Particles—inches
0.02
0.04
0.08
0.12
0.16
0.2
#200
#100
#60
#40
#30
#20
#16
#10
#8
#5
Sieve Numbers.
EUGENE DIETZGEN CO., CHICAGO.

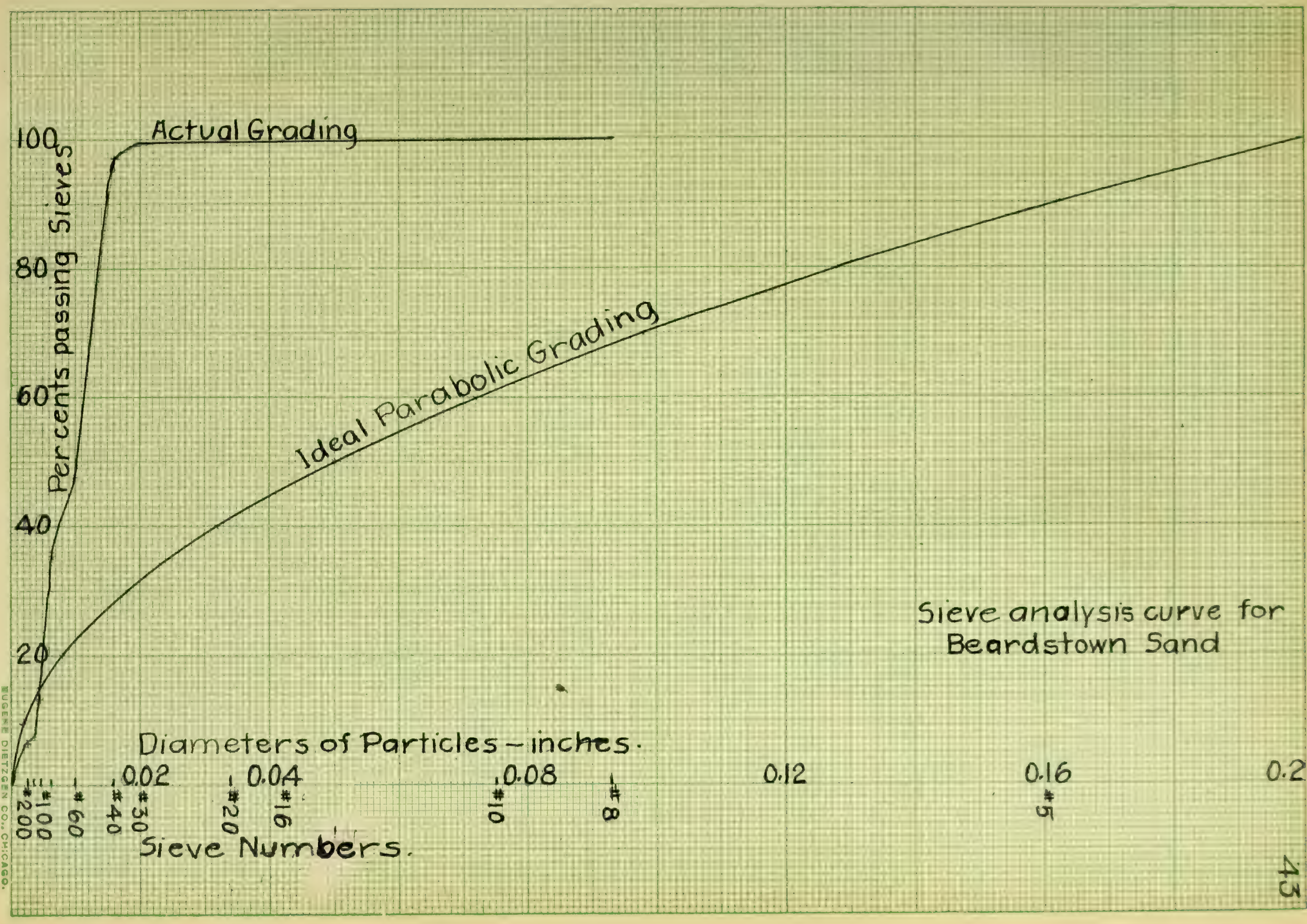

Sieve analysis curve for
Waukegan sand.
Actual Grading
Ideal Parabolic Grading
Per cents passing Sieves
100
80
60
40
20
Diameters of Particles—inches
0.02
0.04
0.08
0.12
0.16
0.2
Sieve Numbers.
#200
#100
#60
#40
#30
#20
#16
#10
#8
#5


Sieve analysis curve for
Moline Sand
Actual Grading
Ideal Parabolic Grading
Per cents passing Sieves
100
80
60
40
20
Diameters of Particles - inches
0.02
0.04
0.08
0.12
0.16
0.2
#200
#100
#60
#40
#30
#20
#16
#10
#8
#5
Sieve Numbers.
40
EUGENE DIETZGEN CO., CHICAGO.



Actual Grading
Ideal Parabolic Grading
Per cents passing Sieves
100
80
60
40
20
Sieve analysis curve for Joliet sand.
Diameters of Particles—inches
0.02
0.04
0.08
0.12
0.16
0.2
#200
#100
#60
#40
#30
#20
#16
#10
#8
#5
Sieve Numbers
41.
EUGENE DIETZGEN CO., CHICAGO.


Actual Grading
Ideal Parabolic Grading
Percents passing Sieves
100
80
60
40
20
Sieve analysis curve for
Little Vermilion R. Sand.
Diameters of Particles—inches
0.02
0.04
0.08
0.12
0.16
0.2
#200
#100
#60
#40
#30
#20
#16
#10
#8
#5
Sieve Numbers.
EUGENE DIETZGEN CO., CHICAGO.
42



Actual Grading
Ideal Parabolic Grading
Percents passing Sieves
100
80
60
40
20
Diameters of Particles - inches.
0.02
0.04
0.08
0.12
0.16
0.2
Sieve Numbers.
#200
#100
#60
#40
#30
#20
#16
#10
#8
#5
Sieve analysis curve for
Beardstown Sand